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HIGH CAPACITY BUS DEVELOPMENTS IN EUROPE: TRIP REPORT, MARCH 1982

by

R.F. Webb Corporation Ltd.

Ottawa, Ontario

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17. Abstract

The report describes the author's findings on European high capacity bus and alternative fuel developments gained through visits to London Transport (U.K.); the Netherlands Road Research Laboratory (Delft, Holland); the Amsterdam Transit Authority (Holland); Vialle Autogas Systems (Eindhoven, Holland); DAF (Eindhoven, Holland); Saurer AG (Arbon, Switzerland); MAN (Munich, W. Germany); Daimler-Benz AG (Stuttgart, W. Germany) and Neoplan (Stuttgart, W. Germany).

Double-deck bus production is increasing, particularly for the European luxury tour market and for export to the U.S. for commuter service. Articulated buses are the preferred intra-city high-capacity option and doubly articulated versions are on test. Data was provided by manufacturers on the comparative economics, safety and performance limits of conventional, articulated and double-deck buses. Information was obtained on hybrid drive trains for buses and on recent developments in the design and testing of bus and truck engines redesigned for propane and methanol fuel.

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17. Résumé

Ce rapport fait le point en ce qui concerne le dossier des autobus grande capacité et les carburants de substitution en Europe. Il fait suite à une tournée européenne qui a conduit l'auteur chez les entreprises et institutions suivantes: la Régie des Transports Londoniens (R.U.), les Laboratoires de recherche routière des Pays-Bas (Delft, Hollande), l'Administration des transports en commun d'Amsterdam (Hollande) et les sociétés Vialle Autogas Systems et DAF (Eindhoven, Hollande), Saurer AG (Arbon, Suisse), MAN (Munich, RFA) et Daimler-Benz AG et Neoplan (Stuttgart, RFA).

Le rapport souligne que la production d'autobus à impériale est à la hausse et qu'elle est destinée surtout au marché du grand tourisme routier européen et aux services de transports en commun de banlieue des Etats-Unis. Du côté strictement urbain, la préférence va aux autobus articulés et l'on procède même à l'essai de véhicule à double articulation. Un chapitre du rapport est consacré aux données comparatives fournies par les constructeurs quant aux coûts, performances et sécurité des autobus classiques, articulés et à impériale. Enfin, le rapport aborde la question des autobus à chaîne de traction hybride et les derniers développements à survenir en matière de conception et essais de moteurs d'autobus et de camions adaptés à la consommation de gaz propane et de méthanol.

18. Mots-clés	19. Diffusion
Autobus, grande capacité, articulé, à impériale, hybride, carburants de remplacement, gaz propane, méthanol, diesel, économie, Europe.	Disponibilité d'exemplaires en nombre limité au CDT.

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1. INTRODUCTION

The Transportation Development Centre kindly provided incremental funding and introductions arranged by Telex to enable Dr. R.F. Webb to visit certain European bus and engine manufacturers, transit authorities and a research centre in the company of representatives of Voyageur Colonial Ltd. (Vice President, H. Chardola) and the Ottawa-Carleton Regional Transit Commission (General Manager, J. Bonsall; Chief Engineer, P. Newgard).

While the principal area of investigation supported by TDC on the visit concerned high capacity bus operations, notes are also provided on related developments in the energy field - in particular developments in engines designed to operate on non-petroleum fuels and various hybrid systems, since this is an area of expanding interest for TDC.

Visits were made to:

London Transport, England

Road Research Laboratory, Delft, Holland

Amsterdam Transit Authority, Holland

Vialle Autogas Systems, Eindhoven, Holland

DAF, Eindhoven, Holland

Adolph Saurer AG, Arbon, Switzerland

M.A.N., Munich, W. Germany

Daimler-Benz, Stuttgart, W. Germany

Neoplan, Stuttgart, W. Germany.

2. HIGH CAPACITY BUS FINDINGS

2.1 Double Deck Buses - Neoplan Capability

A visit was made to the Stuttgart plant of Gottlab-Auwaerter GmbH (Neoplan) to inspect equipment, manufacturing facilities and to conduct discussions with the president and principal owner (Mr. H. Auwaerter) and the Sales Manager (Mr. H. Zeller). Discussions were also held with London Transport's Engineering Division and with DAF (Holland) concerning double deck buses and their potential application in Canada.

The company (Neoplan) manufactures double deck buses, special buses and touring coaches and has also produced a very limited number of articulated single deck buses, including one on test by Voyageur. A special type of bus for European touring service is the company's articulated double decker. It is the largest producer of double deck buses with current production in excess of 500 a year. The company's total coach and bus output from 3 plants in Germany, 1 in Ghana, 1 in the U.S. in 1981 was exactly 1000. (U.S. 58; Ghana 90; German plants 852). A company book on the double deck bus (Reference 1) and a previous report by Webb (for TDC and Pacific Coach Lines, Reference 2) give details of the company's double deck buses.

Neoplan's sales of double deckers are expanding rapidly (50% per year increase for the past 2-3 years) after previous years of modest growth.

2.2 Rationale for Double Deckers

The principal reasons for the current expansion of double decker requirements were given by Neoplan as:

1. Expansion of the luxury touring business in Europe.

2. The fuel economy/passenger offered by the double deck bus compared with the lower capacity of single deckers.

3. The low noise and view obtainable in the luxury double deck version.

4. The French law which currently prohibits use of articulated high capacity buses in France, which means that the double deck bus is the only high capacity option allowed in, or through, French territory. This law may be repealed in 1982/3, DAF states, which could influence this segment of the luxury double decker market.

5. The increasing availability of routes for 4 to 4.1 metre high double deckers, which routes are being swept by tractor-trailer combinations of the same maximum height.

6. Concentration on the luxury market (also for luxury commuting) overcoming the previous impressions of double deck buses as uncomfortable workhorses created by the use of "utility-type" double deckers by London Transport.

7. Special orders placed for double deck luxury units for Saudi Arabia (60-70 per year sold recently) intercity services.

8. The start-up of intercity transport use and especially suburban community services in the U.S. The "park and ride" application in Los Angeles accounted for 20 units in 1981 (26 now sold and delivered). A recently introduced service in England with Neoplan double deckers competes with rail at lower cost and higher frequency of service on the route between London and Plymouth and is expected to expand rapidly. (The German authorities were unaware, though, of the Pacific Coach Lines' interest in 4 units for the trial service between Vancouver and Victoria in B.C.).

9. Recognition of the improved handling available with the double deck bus versus the articulated high capacity option (improved turning radius, lack of complex turning axle requirements, avoidance of hinge stress problems and lack of control on braking often found in articulated buses).

Although the company manufactures articulated buses (an order for 46 pusher type articulated buses has been received from Spokane, Washington), it prefers to market double deckers for these applications.

The disadvantages noted for double deckers are:

1. Lack of luggage space compared to conventional single deck coaches (which may have 4 metre height also).

2. Space occupied by stairways is unproductive.

3. Point made by DAF: the safety factor for the driver in collisions is reduced, since he must be located at a low level in the vehicle; in conventional touring coaches and single deck articulated coaches the driver space is not confined by the presence of an upper deck and improved driver survival rates are therefore quoted. A study of German tests on this aspect of vehicle safety was provided by DAF (Reference 3).

2.3 Relative Economics of the Double Decker

A detailed study made by DAF in 1981 of the capital and operating costs of 75 seater double deck buses, two levels of articulated bus (70 seater) and of a conventional touring bus operated with 30 passengers and 50 passengers was provided by DAF (Reference 4). The touring service required vehicle operation only 150 days per year, but the ratio of total operating costs per passenger showed the double deck version not to be the lowest cost:

In touring service (DAF estimates)

		Relative Cost per Passenger Journey	Capital Cost per Seat
Double deck	75 seats	104.5%	164%
Articulated	70 seats	98.7%	139%
Conventional	50 seats	100.0%	100%
Conventional Single Deck	30 seats	144.0%	128%

The conclusion is that economy of operation is not the predominant factor in the choice of the double deck configuration in transit service. (This conclusion was confirmed by Neoplan, but their economic comparisons were not obtained).

The DAF report can be used to develop details of the costs of other types of service (such as commuting service, such as Quebec-Montreal-Ottawa) for the different vehicle configurations at various passenger load factors. Passenger convenience and passenger conceptions must be important in the decisions made by tourist service companies to purchase double deck units for that service when other configurations appear from DAF data to be more profitable. According to Voyageur's Vice President, similar considerations will apply to intercity transport where the double deck configuration might have appeal for a reinstated commuter luxury service between Quebec and Montreal and between Montreal and Ottawa. Less luxurious double deck configurations may provide low cost commuter and intercity operation when high load factors are available.

2.4 Safety

Discusssions with DAF, Neoplan and London Transport concerning the passenger safety aspects of double deck buses produced the following:

London Transport's experience is predominantly with utility vehicles used in urban service with an open rear platform where passenger accident rates are more frequent than with buses with driver-operated passenger doors, but at the sacrifice of loading time and hence, vehicle productivity (a pertinent paper on bus boarding and alighting times by the British Transport Road Research Laboratory was provided - Reference 5). The open platform option is not viable in Canada.

The principal area of safety for intercity transport concerns the stability of the vehicle at high speed in cross winds, where London Transport reported experience in an experimental London to Birmingham route, where problems were encountered with a rear-engined vehicle, but not with the conventional British (Leyland) front-engined version. Neoplan has experienced no problems in this regard, even though their double deck coaches are used in cross mountain (Pyrenees, Alps) service. Note the

height limit in Europe of 4.1 metres is lower than that used in British buses (4.3 metres).

The other principal area of safety concerns passengers on the stairs. This is claimed to be no problem in intercity service (infrequent stair use) with appropriately designed stairways (facing rearward preferred), but is the second source of accidents in London Transport Service (the first being stepping on/off the rear platform when the vehicle is stationary or in motion).

2.5 Conclusion on Use of Double Deckers in Canada

The high level of interest in the U.S. on the use of double deck buses for intercity transport (especially a luxury executive class service) and particularly for commuter-type service (including park and ride) indicates a need for a more comprehensive investigation of this option which, though limited in scope, may offer ride quality advantages over intermediate distance (10-150 km) travel in Canada.

Neoplan offered to make a double deck bus available on loan in 1982/3 to conduct tests at selected sites in Canada if investigations by TDC, one bus property, or other responsible parties (touring services for example) indicate a service quality, cost saving, or energy saving potential on specific routes. (Contact Mr. A. Auwaerter).

2.6 Double Deck Manufacture

A tour of the Neoplan plant showed that the double deck bus assembly operation is labour intensive, requiring little capital investment for machinery. The Neoplan plant consists essentially of a welding, sheet handling/cutting assembly and finishing operation.

The bus frames are welded tubular steel, no separate chassis being required (monocoque construction). The engines, gear boxes, transmissions and wheels are purchased items to the customer's choice (principally in the German plant Daimler Benz diesel engines with ZK transmissions), the lattice work structure with axles and engine assembled being stabilized by the floor structures and by the sheet steel skins subsequently spot welded. The fittings, such as seats, are purchased items and contribute greatly to the comfort and luxurious appearance of these buses. Neoplan provides a high degree of choice in the final finish of the bus; most can be considered custom-made for each operating company.

No articulated double deckers were under construction, but 3 units which had been taken in exchange for new vehicles were being reworked. They had been fitted with two toilets, a bar, two stairways and seating for 110 touring passengers, a Shink hinge (same as used in Neoplan single deck articulated buses) and a steerable rear axle. It is understood that 6 double deck articulated units have been sold for tour service in the western U.S. and a number also in Saudi Arabia, but the German luxury touring industry is the major customer.

Given a modest domestic or N. American market (say 150 units/year), there is no reason why double deck buses could not be designed and manufactured in Canada. London Transport Engineering Department, with its experience in both intercity and rural service (now transferred) and, until recently, in the design of double deck buses, could provide assistance to a potential Canadian manufacturer. London Transport Engineering can provide consulting and test services under contract (the contact is: T. Lowe, Technical Director, London Transport Executive). They provided an introduction to Leyland Motors (Bus Division), should that be of interest. Leyland can supply double deck buses or chassis. (A Leyland literature package is available, Reference 6).

DAF has manufactured double deck buses to special order (for a British tour firm and the city of Darlington), but recommended against them for both intercity and intracity use (mainly on economic grounds and the German safety report). Other manufacturers were cited: Saab-Scania and Volvo, Sweden; Van Hool, Holland; MAN (revived business and interest) and Daimler Benz, Germany; Hestair Dennis Ltd., Duple International Ltd. and Leyland, U.K.

(It is of interest to note that the Austrian subsidiary of MAN builds double deck buses with propane engines - both the diesel/propane dual fuel type and a modified "100% propane" spark ignition engine).

2.7 Other Considerations

Discussions on double deck buses with London Transport encompassed several areas of interest to their big city bus operations, which may not be applicable in Canada (fare collection systems - use of a driver without a crew; boarding-alighting-vehicle stop logistics; crewed door vs. no door vehicles; vehicle life extension; brake application/mile; double deck seating/standing regulations and experience; double deck bus testing, especially tilt tests; preferred diesel engine suppliers (Gardner for 180 HP engine); gear box options; retarders; preferred transmission; turbocharged vs. naturally aspirated engines; fuel economy experience at various speeds and stopping frequencies and fuel economy test methods used for buses; improvements made in fuel economy through materials selection (use of maximum aluminium reduced 64-69 seat vehicle weight from 10 to 7.25 tonnes), control of vehicle acceleration and change points (8% savings); lowering of engine idle speed; fuel costs.

Of note is the lack of incentive to switch from diesel fuel: quality is high (52 cetane number) and there is no cost advantage for propane in the U.K. Their test experience with a double deck diesel engine converted to LPG (with spark ignition and a Dutch carburetion system added) was described (Reference 7).

3. ARTICULATED BUSES

3.1 General Awareness of the Option

Although articulated buses represent a recent development in N. America, their manufacture and use in Europe are established and widespread. There is extensive literature available and experience within TDC gained from the TDC sponsored current test program at Voyageur. Despite current problems with the integrity of the Neoplan (Shink) hinge, the type of articulated vehicle represents established technology, which must be retested here to evaluate the preferred type of service (intra/intercity), optimum types and the effect of the Canadian environment on vehicle performance, maintenance, safety and economics. European experience is helpful, but not sufficient. Brochures and data on articulated buses were collected from DAF, Saurer and MAN. These are collected as Reference 8.

3.2 High Capacity Articulated Buses

European experience with articulated buses has now been extended to doubly articulated prototypes of bus systems which are being tested. One was seen at the MAN test track in Stuttgart. The double articulated buses will carry 72-80 sitting passengers and 144-150 standing passengers - a total of 225-230 persons per vehicle, while still conforming to the European regulations (8-10 persons/m3). The doubly articulated bus is described in literature provided by MAN (Reference 9). The following data are pertinent:

Passenger Load for City Service: 225-230 (150% of conventional articulated, 220% of standard city bus)

Length: 23m

Axles: 4, 2 driven axles; trailing rear axle steered with cornering movements automaticlly controlled by mechanical linkage to second turntable coupling.

Gross Vehicle Weight: 32.5 tonnes (exception to current 20 tonne limit).

Engine: 280 HP turbocharged diesel (trolley bus version available also).

Outside Turning Radius: 12 metres (same as 16.5 m two section, articulated bus).

Manning: One operator-driver contemplated (fare collection problems ?)

The operating cost savings for this version are obvious (and can be developed from DAF data). Daimler-Benz is similarly testing prototypes of doubly articulated buses.

3.3 Guided Articulated Buses

Some information on the guided bus option was provided in a report to TDC, dated October 1981, by Lee Sims (Reference 10). The option is being worked upon by both Daimler-Benz and MAN and is a hybrid of electric trolley car systems and articulated bus systems technology. Daimler-Benz systems encompass a mechanical (steel or concrete rail) system and an electronically controlled (buried pilot cable issuing an audio frequency AC signal), more versatile, electronic guide system used in dedicated rights of way (including tunnels) with conventional diesel buses, electric trolley cars and hybrids. The best economics are available from high capacity, articulated buses, which may compete with LRT. The Daimler-Benz "O-Bahn" system is illustrated in the references they provided (Reference 11); the MAN systems are similar (Reference 12), both having been developed with Robert Bosch and Dornier with financial aid from the German Ministry of Research and Technology.

3.4 Hybrid Buses

A paper was presented by Daimler-Benz personnel to the group on the energy considerations involved in hybrid buses using diesel engines coupled with battery drive, or direct electric traction and a trolley/battery option. The presentation followed a published paper provided by Daimler-Benz (Reference 13). In addition to the paper the following is relevant:

- Daimler-Benz is funded by various government agencies to conduct hybrid R&D and to continue technical support of the trolley (tram car) systems. The original justification for electric trolley and battery developments was pollution: this is less relevant today.

- A total of 20 hybrid Elektrobuses have been in use for 3 years in Stuttgart/Wesel and a further 5 have been put into service at Esslingen.

- The major development in trolley-buses is a semi-automatic system for relocating the trolley arms (they automatically seek the overhead cable and make the electric connection).

- The major problems associated with battery-containing hybrids are:

  1. Weight: for a 30 km range 2 packs of batteries each weighing 1.5 tonnes are required.

  2. Hydrogen emission from the battery requires installation of a special venting system and flame proof motors and switches.

  3. Battery recharging is highly exothermic, requiring the installation of air or water-cooling systems for the batteries in the electric trolley/battery version.

  4. The electric trolley-battery hybrid requires extensive electrical insulation between the cable-electric drive system and the battery system.

5. To date batteries have given only 1200 cycles (a maximum of a 2 year life).

Daimler-Benz concludes that the electrical-battery option is exceptionally expensive with high maintenance costs and that any mode of operation which utilizes a diesel engine/diesel fuel in the hybrid is preferred to the all-electric options.

Daimler-Benz believes the hybrids being investigated are long term and emergency options. A similar view of hybrid electric drives (battery-electric) prevailed at MAN.

London Transport Engineering is extremely interested in a diesel-flywheel hybrid option and strongly recommends contact be made with the Development Corporation of Israel, which is working with GM. The latter may offer a 4 ton delivery van with a flywheel hybrid in the near future. (Further detail can be obtained from D. Locker, Manager, Industries Development Corporation (International Services) Co. Ltd., Automotive Systems Division, P.O. Box 8750, Tel Aviv 61087, Israel).

MAN work on regenerative energy drive systems included a diesel-flywheel and a diesel-hydraulic storage system. Prototypes of both systems have been operated for 2 years or more on an experimental basis.

4. ALTERNATIVE FUELS

The outstanding alternative fuel developments noted were:

4.1 Propane

1. The development by Saurer of Switzerland of a propane engine (spark ignition version of a derated diesel engine) which has been extensively tested by the Swiss Post (who operate Swiss public transport). The Saurer system appears to be that preferred by OC Transpo and Voyageur for the 20 vehicle demonstration program each is preparing. A truck application has also been demonstrated by Saurer. A similar package is available from the Austrian subsidiary of MAN (OAF).

2. The development by TNO (the Dutch road research laboratory) of a kit for the conversion of diesel engines to a propane-diesel dual operation. This kit technology is judged to be superior to that planned by Space Fuel Systems (and Mohawk Oil) and a contractual arrangement between TNO and the Calgary company would expedite the Canadian development. The Dutch technology continues to be applied commercially by the Vienna Transit Authority.

The propane technology is reported in Reference 14.

4.2 Alcohol Fuels

1. The development by Daimler-Benz of a system for the evaporation of methanol to produce an air-methanol intake to a high compression carburetted spark ignition system wherein the methanol serves as a heat sink recuperating 20% of the exhaust gas thermal losses. The use of methanol as a gaseous fuel avoids many problems formerly associated with methanol use (cold start and hot weather fuel vapour lock, lack of lubricity for direct injection and cylinder wear), increases the thermal efficiency (recuperation), and provides for the eventual increase in thermal efficiency through catalytic cracking of the methanol with heat supplied by the exhaust gases. The high compression engine (12:1 compression ratio) combined with recuperation provides high efficiency with an existing engine (modified). After vapourization of the methanol, the methanol engine is identical to the propane engine of Saurer (and MAN). (Reference 15).

2. TNO has developed a sensor which provides a measure of the alcohol content (methanol or ethanol by refractive index measurements) of gasoline/alcohol/water blends and means to adjust the air/fuel ratio (an automatic carburettor adjustment) to the engine to

compensate for the alcohol and water level. A drive was taken in a methanol-fuelled car which switched to gasoline without hesitating. It is reported that the engine works well on either of the separated layers of a wet methanol-gasoline blend (Reference 16).

4.3 Alcohols with Diesel Fuel

Daimler-Benz and MAN have developed systems for the partial and total replacement of diesel fuel in compression ignition engines with ethyl alcohol or methyl alcohol. Both companies are operating experimental vehicles, with Daimler-Benz manufacturing alcohol-fuelled vehicles in Brazil. The technologies are unexceptional and widely reported in the literature, with the exception of Daimler-Benz work on the development of fuel compositions which overcome the problems normally associated with alcohol fuels relating to poor fuel ignitability (low cetane number increased by D-B with nitrate-type boosters), low lubricity (addition of selected indigenous vegetable oils to the alcohol or alcohol/diesel blend). The work is described in a 1980 paper by D-B personnel (Reference 17).

4.4 Other Alternatives Noted

Some discussion was held and literature obtained on experimental vehicles and prototypes operating on other alternative fuels:

1. Battery-driven buses (MAN (Reference 18).
2. Compressed natural gas buses (MAN, Daimler-Benz, TNO).
3. Liquid natural gas bus operated since 1972 by MAN.
4. Hydrogen (metal hydrides and liquid hydrogen, hydrides in hybrids).

Daimler-Benz has a field full of vehicle prototypes being tested using alternative fuel and new configurations.

5. OTHER ITEMS OF POSSIBLE INTEREST

5.1 TNO Test Facility

TNO has conducted crash and burning tests on propane-fuelled vehicles and propane tanks and is probably the leading world authority on propane safety in vehicles and large-scale storage. It operates on a contract basis. Movies are available on fire tests conducted on diesel and propane buses and crash tests on propane vehicles (automobiles, bus) and storage tanks.

5.2 Bus System Planning

MAN provided useful booklets on bus planning and future urban transit options. Indexes of these books are provided as References 19 and 20. Copies of the original can be provided if required.

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